New approaches in breakout prediction

M. Langer, M. Arzberger
SMS Demag Automation: 
New approaches in breakout prediction

Dipl.-Ing. Martin Langer, Dipl.-Ing. Matthias Arzberger
SMS Demag Aktiengesellschaft, Düsseldorf and Hilchenbach, Germany

Introduction

The task of detecting and preventing breakouts is as old as continuous casting technology itself. Of all the processes hitherto used (measurement of temperature, friction force, withdrawal force, vibration and structure-borne noise), the measurement of temperature by means of thermocouples at the mould copper plates has proved to be the most suitable and most reliable method.

Thanks to close cooperation and full utilization of all the synergies between automation, mechanical design, process engineering, metallurgy and leading steelworks customers, a system has been created which has assumed a pioneering role in the market for breakout early-warning systems. This system is known as the SMS Demag Breakout Prediction System (BPS).

SMS Demag supplies the complete solution from one single source, the “Plug and Cast” concept which also includes competent and long-term service to our customers.

Data collection

The basis for a successful BPS is reliable data collection which, in the rough environment of continuous casting technology, transmits plausible measuring data at all times from the sensors installed in the mould.

With the growing need for top-class product quality, the number of sensors in the moulds has increased considerably. While at the beginning of the development it was customary to have two rows of thermo-couples, nowadays three or more rows are used. The focus is no longer exclusively on early detection of breakouts but also on the monitoring of heat dissipation and the contact between the strand shell and the mould.

It is therefore not unusual for individual moulds to be equipped with 100 or more thermosensors. This large number of sensors automatically requires a great deal of cabling and coupling. In addition to the high investment costs, the maintenance expenses are also considerable.

The standard design used today is the multifunction coupling shown in figure 1 which was developed for use in a rough environment. Thus, for example, in a facility currently in use, four such multicouplings are required to connect about 100 temperature sensors. The sensors are connected to the multicouplings via temperature-resistant master cables.

A new solution - field bus technology at the mould

Thanks to the data transmission system recently developed by SMS Demag, distinct progress has made with regard to minimizing the cabling and maintenance expenses.

By using the new type of field bus modules (with IP67 type of protection) for decentralized pre-processing of data, measured values are already
recorded in digital form on the mould. The modules, which are equipped with 4 channels each, are connected via profibus (in cascade form). Figure 2 shows the opened water-cooled protective casing which houses the field bus modules.

![Fig. 2. Mould with water-cooled protective casing](image)

The hitherto used multi-strand master cables are replaced by a so-called hybrid cable (bus and energy supply combined in one). Two special plug connectors, which were specially developed for the rough ambient conditions, replace the multi-pole multi-function coupling which is prone to failure, figure 3.

![Fig. 3. Special plug connector with hybrid cable](image)

To replace a thermocouple, the sensor plug connector only has to be released, the thermocouple removed and replaced by a new one. A mould equipped with this technology can already be fully tested in the workshop, figure 4. This new technology can be used for new facilities as well as for revamping existing ones.

The newly developed concept was tested for several months in field trials and is now used in all products supplied by SMS Demag. Initial experience shows that the costs of maintaining the thermocouples and the pertaining cabling have dropped by more than 20%.

The evaluation system - real-time database allows “flight recorder”

In addition to the extensive measuring data of the mould, further process-related data are transmitted to the BPS.

At the required cycle times ranging from a few milliseconds (10 ms for mould level and stopper position) to 250 ms (for temperature signals), all data are saved in a real-time database and archived for several weeks. The evaluation programs procure the data required for active breakout recognition from this real-time database.

In addition to this on-line function, the system also enables the analysis of previously recorded data by playing back complete casting sequences (Flight Recorder). This makes it possible to subsequently examine the process sequence and to optimize the
system in respect of changed conditions (new types of steel, casting powder, casting speeds) by means of simulation. The plant operator obtains in-depth knowledge about the connections between breakout risks and operating practice.

**The algorithms - quick reaction for quick-casting facilities**

The development of near-net-shape casting of thin gauges at high casting speeds has also resulted in the need for a BPS which is capable, within the shortest feasible time, of recognizing potential breakout risks which are primarily caused by so-called stickers and introducing preventive measures. 80 % of the breakouts are caused by stickers.

![Fig. 5. Cause for breakouts](image)

The traditional methods for the recognition of stickers where certain temperature progressions (signal patterns) have to have taken place before an alarm is triggered are no longer sufficient for quick-casting facilities. This is clearly illustrated by the fact that with an active mould length of approx. 1 m and a casting speed of approx. 6 m/min, an alleged sticker stays only a maximum of 10 seconds in the mould. If the strand, however, is to be given a chance to be cured, the continuous caster must be stopped within virtually two seconds. The speed is then accelerated back to the required production speed with the help of suitable ramps.

![Fig. 6. Alarm state](image)

![Fig. 7. Emergency delay ramps](image)

Algorithms which can tackle this task are based on a rate-of-change process. The rate of increase of all incoming temperature measurements is continuously compared with threshold values. If the value is exceeded, the BPS enters a state in which it is ready to trigger an alarm. In this condition, the temperature progressions are monitored in the immediate vicinity of the initiator. If the threshold value is exceeded here too, the BPS immediately enters the alarm state and an active breakout alarm is triggered.

Further criteria for producing alarm states are abnormal movements of the mould level and the stopper. A newly developed algorithm compares the expected stopper position and movement as functions of material flow, tundish level and tundish and stopper geometry with the actual stopper position and is therefore able to recognize clogging deposits at the tundish spout at an early stage. The operating personnel are warned well in time about any possible wash out of the deposits, which upon entering the mould would then cause inclusions in the strand shell and consequently lead to breakouts. The implemented technological model records any factors insidiously affecting the submerged nozzle which in turn largely also influence the surface quality of the cast product.

**Prevention - reaction appropriate to the situation**

The active alarm is transferred to the control system of the continuous caster. The casting speed is reduced according to a predefined ramp such that a speed of approx. 0.5 m/min is reached within less than two seconds. After a short holding time, the casting speed is again automatically accelerated to the original production speed by using emergency delay ramps. Various types of emergency delay ramps are automatically activated, depending on the manner of formation of the sticker and the steel grade.
The sequence described earlier takes into account the past experiences with various production facilities. The reactions have to be adapted depending on the various steel grades and the pertaining casting powders as well as on the different operating situations. While production is continued after a preventive measure during the casting process, it may be necessary in the event of a breakout alarm being triggered in the startup phase to immediately initiate a sequence abort with automatic withdrawal. A coordinated reaction from the technological control system and the BPS is essential for this purpose. This is how maximum protection against damage can be attained with minimum loss of production.

The transparent mould

In addition to the function of the BPS described above, the sensor system of the mould is being increasingly used to monitor the casting process. With Mould Temperature Mapping – MTM, SMS Demag has developed a system which gives the operating personnel on-line information on the heat dissipation from the mould as well as on the contact between the strand shell and the copper plates. The temperature measurements which are distributed over a network in the mould serve as calculation points for the temperature of the copper plates and provide information on the contact between the strand shell and the mould. At locations which have an abnormally low temperature, a gap will have been formed between the strand and the mould, thereby hampering the necessary heat dissipation and the continuous growth of the strand shell. In the area of the mould corners, this could be an indication of incorrect taper. As a rule, the risk of breakout is greater in such operating conditions.

A user-friendly visual display system shows the temperature maps measured and allows the user to continuously estimate the quality of the casting process. Thanks to this additional complementary function, the breakout detection system has progressed from the plain BPS to become the SMS Demag Mould Monitoring System – MMS and is thus the prerequisite for the transparent mould.

The visual display system - operate, observe and analyze

In addition to the direct reaction of the automation system for the prevention of breakouts, a user-friendly visual display of measurement data and operating states is extremely important. The visual display system for operation and observation purposes is directly linked to the database, figure 9. A graphic editor facilitates the creation of the screen display surfaces which can be adapted to meet the individual requirements of the users.
In addition to the depiction of the operating condition of the mould and the availability of the entire MMS, the process data must also be displayed in a suitable manner, figure 10.

The green background color indicates trouble-free operation. Yellow and red draw the user's attention to abnormal situations which could jeopardize casting. Furthermore, essential information is also shown in the form of process data such as mould level, stopper position, casting speed and integral heat dissipation.

For the analysis of historical data, the system allows the compilation of any number of trend curves and signals.

**Customer support via teleservice**

Assisting our customers in the maintenance and optimization of the automation systems is an integral part of our service.

BPS also has the hardware and software components which enable remote diagnosis. The maintenance staff as well as SMS Demag's service staff can access the system via teleservice and analyze the entire system.

---

**The result: Technology and automation from one single source**

The Mould Monitoring System (comprising BPS and MTM) is an interdisciplinary development from all the departments of SMS Demag. A technological system has been developed which, in a consistent and logical manner, takes account of all aspects, ranging from plant operation to maintenance and down to the minimization of damage losses.

Our customers benefit from our achievements:

- Prevention of sticker breakouts
- Thorough monitoring of the heat transfer in the mould
- Further development of casting technology
- Lower expenses on maintenance
- Quick mould change times
- Steep acceleration curves
- High product quality
- High operational reliability